JKAU: Met., Env. & Arid Land Agric. Sci., **Vol. 16** No. 2, pp. 41-51 (2005 A.D. / 1425 A.H.)

Genotype × Environment Interaction and Seed Yield, Oil and Protein Contents Stability of Soybean Genotypes

F.S. El-Nakhlawy
Arid Land Agric. Dept., Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract. Stability of seed yield, plant height, 100-seed weight, oil and protein content were studied in ten soybean cultivars at Alexandria and El-Hammam, Egypt during 2000, 2001, 2002 and 2003 seasons. Two stability parameters were estimated; *viz.*, linear regression coefficient (b) and deviation from regression (S^2_d) for each cultivar. Significant cultivar × environment interactions were detected for all studied traits. Ranges of b-values were 0.67 to 1.47 for plant height, 0.56 to 1.57 for seed yield, 0.39 to 1.47 for 100-seed weight, 0.66 to 1.47 for oil content, and 0.68 to 1.56 for protein content. Values of S^2_d were significant in three genotypes for plant height and protein content, four genotypes for seed yield, eight genotypes for 100-seed weight, and seven genotypes for oil content. Elgin and Davis were the most stable genotypes.

Key words: Stability, soybean, yield, oil and protein contents.

Introduction

Stability of yield and quality in different environments are of an important consideration in crop breeding programs. Genotype × environment (G × E) interactions are of major concern to plant breeders. Identifying high-yielding and stable crop cultivars is a primary objective of most applied breeding programs. In the presence of G × E interaction, stability parameters are estimated to determine the superiority of individual genotypes across the range of prevalent environments. Many stability measures have been proposed by several investigators. Eberhart and Russell (1966) regressed the mean yield of each cultivar on the mean of all cultivars for each environment. They proposed that a cultivar with a regression coefficient of $b_i = 1.0$ and a deviation from regression mean square $S^2_{di} = 0$ was stable. Finlay and Wilkinson (1963) proposed that a genotype with a high overall mean yield and a "b_i" value of unity was desirable and well adapted to all environments. Shukla (1972) proposed partitioning the G × E sum of squares, with a stability variance component (Q^2_1) for each cultivar. Similar results were obtained by Rao *et al.* (2002) in U.S.A.

Some studies were conducted on stability in soybean crop. Singh and Chaudhary (1985a) in India, showed that PK 73-93 soybean cultivar gave the highest biological yield and was the most stable in the favorable environment. The same authors (1985b) found that genotypic differences and G × E interactions were significant for oil content, but not for protein content. Carver *et al.* (1986) in U.S.A., reported that G × E interaction for each unsaturated fatty acid could be attributed to differences among genotypes in their linear response to changes in environment's mean. Konwar and Talukdar (1986) found significant G × E interactions for studied soybean traits, but the relative contributions of the linear and non linear components of these interactions varied with the character. In Peru, Angeles (1987) evaluated thirteen soybean varieties in four locations and the analysis of data showed that the best varieties for yield were Pelican and Jupiter followed by Forrest and Davies. Bhatinagar and Tiwari (1989) reported significant variety × environment interaction for seed yield. Arrieta *et al.* (1990) in Ecuador, found that P-31 variety was considered a stable genotype with sufficient adaptability and consistent yield across six locations. Sediyama *et al.* (1990) in Brazil, reported that the stability of the studied soybean varieties varied when their performance was analyzed in two sets of environments, poor and favorable. Vernetti *et al.* (1990) in Brazil and Raut *et al.* (1992) in India, reported that the highest yielding soybean variety had the best stability. In Ontario, Canada; Primoma *et al*. (2002) found that genotype × year interaction effect was significant for all fatty acids whereas genotype × location and genotype × year × location interaction effects were significant only for oleic, linoleic and linolenic acids. Rao *et al.* (2002) stated that the genotypes effects were significantly larger than the location × year effects for plant height and seed weight but not for seed yield. Three stable varieties in yield across environments and years were detected.

The objectives of this study were to 1) determine the range of variability for seed yield, some agronomic traits and oil and protein contents in ten soybean cultivars, 2) estimate the stability parameters for the studied traits and 3) identify superior soybean cultivars based on the stability parameters.

Materials and Methods

The present study was carried out in two locations, Alexandria and El-Hammam, during 2000, 2001, 2002 and 2003 seasons. Alexandria location was presented by Alexandria University Farm. The soil is clay, shell, topic and torrifluvents. El-Hammam is 75 km west Alexandria and 7 km south of the coastal line. The sandy soil is clay loam, calcareous, topic and calciorthids (62% sand). The chemical composition of each soil is presented in Table 1.

TABLE 1. Chemical composition of Alexandria and El-Hammam soils.

Location	pH	O.M.	P	Cations			Anions		
		%	(ppm)	Ca^{++}	K^{+}	Na^{+}	HCO_3	SO_3	Cl
Alexandria	8.1	1.83	2.90	7.70	0.81	6.1	5.2	8.2	13.7
El-Hammam	7.6	0.65	0.83	5.50	0.61	7.4	2.1	8.2	13.7

Ten soybean cultivars, namely, Clark, Calland, Davis, Corsoy, Crowford, Essex, Williams, Bouns, Cutler and Elgin were grown at the two locations during 2000, 2001, 2002 and 2003 seasons. Some characters of these cultivars are presented in Table 2.

TABLE 2. Some characters of the studied ten soybean genotypes.

Genotypes	Maturity group	Days from planting to maturity	Origin
Corsoy	II	130	USA
Calland and Williams	III	131	USA
Clark, Davis, Crowford, Bouns and Cutler	IV	136	USA
Essex	V	139	USA
Elgin	VI	148	USA

The experimental design was a randomized complete block with four replications, each plot consisted of eight ridges, 5 m long and 70 cm apart. Seeds were sown on both sides of ridges in hills spaced at 15 cm and were thinned to two plants/hill 20 days after sowing. Plots in the two locations were sown during May 15^{th} to 20^{th} in 2000, May 16^{th} to 19^{th} in 2001, May 20^{th} to 24^{th} in 2002, May 15^{th} to 18^{th} in 2003 seasons. Recommended culture practices for each location were applied. At harvesting, 20 plants were randomly chosen from each plot to measure plant height (cm). A guarded area of 17.22 m^2 per plot was harvested, threshed and seed yield (kg/plot) was determined and converted into kg/ha. Two 100-seed random samples per plot were weighted. Two other random seed samples were used to determine seed oil content, using Soxhlet methods as described by A.O.A.C. (1980). Protein content of seed was determined by using the Kjeldhal method (A.O.A.C., 1980).

Data analysis of variance was performed according to Steel and Torrie (1980). In this analysis, the year and location effects were assumed to be random, while the cultivars effect was considered fixed. Significance of G × E interaction was tested applying the procedure outlined by Perkins and Jinks (1968). This method partitions significance of G × E interactions into a component due to heterogeneity between regressions and a remainder component.

Stability parameters, suggested by Eberhart and Russell (1966) were estimated from the regression analysis. One stability parameter was estimated as the linear regression coefficient (b) of an entry mean on the average of all entries in the particular environment. The other stability parameter was the deviation from regression (S_d^2) for each entry.

For the regression analysis of variance, the residuals from the combined analysis of variance were used as a pooled error to test the S_d^2 values. It was assumed that a significant F-value would indicate that S_d^2 was significantly different from zero.

Results and Discussion

Analysis of variance for plant height, seed yield, 100-seed weight, oil and protein contents of the studied soybean cultivars is presented in Table 3. Location effect was highly significant for all studied characters as well as years effect, except for plant height. In the mean time, location × year interaction was highly significant for all studied characters. Similarly, cultivars effect was highly significant in all cases. The first and second order interactions were almost highly significant between cultivars on one side and each of ocations, cultivars and years, on the other side, for all traits. The presence of significant second-order interaction indicated that there were significant changes in cultivars × locations effects among years. These results were further clarified by the high significance of environments and cultivars × environments interaction for all studied traits (Table 3). Similar results were reported by Singh and Chaudhary (1985b), Konwar and Talukdar (1986) and Bhatinagar and Tiwari (1989) who found that genotype × environment interactions were significant for soybean studied traits.

Partitioning environments × cultivars interaction into components; *i.e.*, the heterogeneity between regression and the remainder components showed the two components were highly significant for all characters under study (Table 3). This confirms the presence of G × E interaction in the present investigation, as shown by Perkins and Jinks (1968). Besides, the significance of heterogeneity between regression for all traits, through testing against the remainder mean squares, suggested that there were significant differences in regression coefficient values among soybean cultivars.

TABLE 3. Analysis of variance for plant height, seed yield, 100-seed weight, oil and protein contents of 10 soybean cultivars based on 4-year data from two locations.

Source of variation	d.f.	Mean squares				
		Plant height (cm)	Seed yield (kg/ha)	100-seed weight (g)	Oil content (%)	Protein content (%)
Locations (L)	1	17588**	23268384**	393**	20.28**	2091**
R (L)	6	2.73	8147	0.19	2.50	0.09
Years (Y)	3	5.50	54390**	13.05**	11.03**	2.71**
L (Y)	3	35.23**	259131**	10.52**	17.83**	3.70**
RY (L)	18	2.81	2496	0.15	1.50	0.16
Cultivars (V)	9	773.0**	561077**	48.68**	17.30**	48.03**
L V	9	387.0**	79982**	11.62**	8.46**	4.36**
Y V	27	37.59**	19526**	1.70**	3.25*	2.93**
L Y V	27	25.67**	20524**	1.34**	4.05**	4.05**
Environments (E)	7	2529.6**	2458421**	66.24**	15.26**	301.5**
V × E	72	82.40**	28590**	2.96**	4.34**	3.16**
Heterogeneity	9	349.80**	106355**	13.86**	20.43**	12.1**
Remainder	63	28.40**	13037**	0.79**	1.11**	1.37**
Error	216	5.27	2440	0.14	0.55	0.14

*,**Significant at 0.05 and 0.01 probability levels, respectively.

Data presented in Table 4 show the seasonal means of seed yield (kg/ha) for each genotype overall four seasons and two locations. The data revealed that Elgin genotype occupied the first rank followed by Davis genotype, then Essex genotype in the four studied seasons, also as overall mean of these seasons. As for the stability parameters Elgin, Davis and Crowford had regression coefficients close to unity and small deviation from regression values, *i.e.*, regression coefficients were 1.09, 0.98 and 0.89 for Elgin, Davis and Crowford, respectively and the deviation from regression values were 899, 942 and 1160 for the three genotypes, respectively. These results mean that Elgin and Davis genotypes were the most stable and highest seed yield among the ten genotypes followed by Essex genotype under the two locations, Alexandria and El-Hammam and the four studied seasons.

Data of Table 5 reveal that plant height overall mean values ranged from 29.1 to 38.9 cm, at El-Hammam and from 39.2 to 62.1 cm at Alexandria. In the former location, Elgin, Bouns and Williams were the tallest cultivars, with heights

TABLE 4. Mean seed yield for ten soybean cultivars under four seasons and two locations and their stability statistics.

Cultivars	Seasonal mean (kg/ha)				Overall mean	Stability statistics	
	2000	2001	2002	2003	(kg/ha)	b	S^2_d
Clark	852^{e+}	807^{f}	820^{f}	849^{f}	832^{g}	0.60	717
Calland	913^{d}	776^{f}	834^{f}	957^{c}	870^{f}	0.74	1965^{**}
Davis	1194^{a}	1100^{b}	1120^{b}	1194^{a}	1152^{b}	0.98	942
Corosoy	930^{d}	874^{e}	901^{e}	894^{e}	902^{f}	0.80	1043
Crowford	993^{c}	927^{d}	960^{d}	911^{de}	948^{e}	0.89	1160
Essex	1112^{b}	1040^{c}	1102^{b}	1058^{b}	1078^{c}	1.37^{*}	1786^{*}
Williams	823^{ef}	844^{f}	819^{f}	718^{g}	801^{g}	0.64	2034^{**}
Bonus	786^{f}	753^{g}	777^{g}	794^{g}	773^{h}	1.57^{*}	743
Cutleer	1121^{b}	1041^{c}	1036^{c}	963^{c}	1025^{d}	1.36*	1773^{*}
Elgin	1200a	1169a	1182a	1208a	1190a	1.09	899

*,**Significant at 0.05 and 0.01 probability levels respectively.
+Means followed by the same letter(s) are not significantly different according to L.S.D. at 0.05 level.

of 38.9, 38.4 and 37.7 cm, respectively. However, at Alexandria, Calland cultivar was the tallest (62.1 cm), followed by Williams (59.6 cm).

Considering seed yield, data in Table 5 further show that Elgin cultivar produced the highest significant seed yield, followed by Davis at the two locations. Their successive mean values were 786 and 750 kg/ha in El-Hammam location and 1593 and 1554 kg/ha in Alexandria location. Similar results on Davis cultivar were reported by Angeles (1987). Further, seed yield overall means ranged from 502 kg/ha (for Williams) up to 786 kg/ha (for Elgin), at El-Hammam location and from 930 kg/ha (for Bonus) to 1593 kg/ha (for Elgin) at Alexandria location.

As for 100-seed weight, the overall mean values differ from 9.77 g (for Bonus) to 14.70 g (for Davis) at El-Hammam location, and from 18.65 g (for Bonus) to 26.93 g (for Davis) at Alexandria location. Besides, comparing the oil content for the studied genotypes (cultivars), it ranged from 20.30% (for Bonus) to 23.1% (for Elgin), at El-Hammam location, and from 20.85% (for Williams) to 24.81% (for Elgin) at Alexandria location. Moreover, the seed protein content of soybean cultivars ranged from 31.45% (for Williams) to 34.80% (for Corosoy), at El-Hammam location, and from 36.88% (for Bonus) to 41.83% (for Elgin) at Alexandria location.

TABLE 5. Mean values of plant height, seed yield, 100-seed weight, oil and protein contents for 10 soybean cultivars under two locations combined over 4 years.

Soybean cultivars	Plant height (cm)		Seed yield (kg/ha)		100-seed weight (g)		Oil (%)		Protein (%)	
	El-Hammam location	Alexandria location	El-Hammam location	Alexandria location	El-Hammam location	Alexandria location	El-Hammam location	Alexandria location	El-Hammam location	Alexandria location
Clark	35.7c*	55.2c	538d	1095f	10.97f	20.42g	20.44f	22.81c	31.69f	38.06f
Calland	33.6d	62.1a	618c	1122f	11.72c	21.60f	21.14e	21.64e	32.30e	38.36e
Davis	30.1ef	45.1g	750b	1554b	14.70a	26.93a	22.64b	23.43b	34.44b	40.06bc
Corosoy	36.7bc	42.9i	551d	1253e	9.85g	22.21e	20.35f	21.15f	34.80a	40.34b
Crawford	32.7d	51.4e	613c	1282de	12.83d	21.47f	21.47e	22.01d	32.55d	40.09c
Essex	29.1f	43.4h	738b	1418c	11.94e	22.75d	22.19c	22.49c	34.65a	39.92c
Williams	37.7ab	59.6b	502e	1099f	8.94h	20.31g	21.99d	20.85f	31.45g	37.90g
Bonus	38.4a	53.1d	600c	930g	9.77g	18.05h	20.30f	21.90de	33.10c	36.88h
Cutler	30.9e	39.2j	740b	1310d	12.80c	23.82c	22.62b	23.54b	32.46de	39.72d
Elgin	38.9a	46.9f	786a	1593a	13.08b	25.34b	23.10a	24.81a	34.70a	41.83a

*Means followed by the same letter(s) in the same column are not significantly different according to LSD at 0.05 level of probability.

Stability Estimates

Stability parameters were estimated by the method of Eberhart and Russell (1966) who proposed the linear regression coefficient and the deviation from linear regression as two essential parameters for estimating stability of genotypes. They defined a stable genotype as one with a regression coefficient close to unity, with deviation from regression as small as possible. The regression coefficient (b) values for the ten cultivars tested in this study ranged from 0.67 to 1.47 (for plant height), 0.56 to 1.57 (for seed yield), 0.39 to 1.49 (for 100-seed weight), 0.66 to 1.47 (for oil %) and from 0.68 to 1.56 for protein percent (Table 6). These wide variations in b-values suggested that the ten cultivars differently responded to the dissimilar environments under which they were grown. In fact, variability among environments is an important factor and to a large extent determines the usefulness of b-values (Pfahler and Linskens, 1979).

Mean squares for deviation from regression (S_d^2 -values) are considered the most appropriate criteria for measuring phenotypic stability in an agronomic sense because this parameter (S_d^2) estimates the predictability of genotypic reaction to environments (Becker *et al.*, 1982). Significant values of deviation from regression (S_d^2), given in Table 6, were obtained for the studied genotypes. In cases of plant height, seed yield, 100-seed weight, oil % and protein %, the significant S_d^2 values were obtained from three, four, eight, seven and three cultivars, respectively. For oil content, for example, Calland, Bonus and Elgin cultivars had insignificant S_d^2 values (2.01, 0.69 and 1.17, respectively).

TABLE 6. Estimates of stability parameters for plant height, seed yield, 100-seed weight, oil and protein contents in 10 soybean cultivars (based on eight environments).

Soybean cultivars	Plant height (cm)		Seed yield (kg/ha)		100-seed weight (g)		Oil (%)		Protein (%)	
	b	S_d^2	b	S_d^2	b	S_d^2	b	S_d^2	b	S_d^2
Clark	0.68	1.36	0.56	717	0.39	0.63^*	0.68	0.67^*	1.18	2.01^{**}
Calland	0.67	1.87	0.74	1965^{**}	1.49^*	0.05	0.66	0.46	0.69	0.39
Davis	1.28^*	3.58	0.98	942	0.95	0.64^{**}	1.17	0.67^*	1.06	0.23
Corosoy	0.88	2.47	0.80	1043	0.96	1.07^{**}	0.74	1.08^{**}	0.93	0.69^*
Crawford	1.47^{**}	3.95^*	0.89	1160	0.86	0.87^{**}	1.07	0.87^*	0.69	0.18
Essex	1.38^{**}	3.86^{**}	1.37^*	1786^*	1.39^*	0.12	1.45^*	2.16^{**}	1.56^*	0.21
Williams	0.76	2.13	0.64	2034^{**}	0.81	2.08^{**}	0.78	4.08^{**}	0.68	0.09
Bonus	0.82	1.70	1.57^*	743	0.76	0.86^{**}	0.87	0.10	0.69	1.17^{**}
Cutler	0.96	2.70	1.36^*	1773^*	1.29^*	0.43^*	1.47^*	0.74^*	1.56^*	0.19
Elgin	1.11	4.20^*	1.09	899	1.18	0.95^{**}	1.10	0.17	0.90	0.20

*,**Significant at 0.05 and 0.01 probability levels, respectively.

Considering the stable cultivars in this study, according to the obtained estimates of the two stability parameters (Table 6) and the overall mean seed yield (Table 4), Elgin and Davis cultivars were the most stable in seed yield because such yield was above average across the eight environments. Besides, the b-values were approximately one (close to unity). In addition the S_d^2 values for the two cultivars were not significantly different from zero.

For plant height, Williams and Calland were the most stable cultivars, because their mean plant height values were the highest overall the eight environments and their b and S_d^2 values were not significantly different from one and zero, respectively.

As for 100-seed weight, seven genotypes had b-values not significantly different from one, while only two, namely, Calland and Essex, had S_d^2 values insignificantly different from zero.

With respect to oil and protein content, Elgin and Davis cultivars had b and S_d^2 values not significant from 1.0 and zero, respectively. Besides, their oil and protein contents were the highest overall in the studied environments. Accordingly these two genotypes were more stable than the others in oil and protein contents.

Results of the present study revealed that plant height, seed yield, 100-seed weight and oil and protein contents were significantly influenced by changes in environmental conditions. For the ten genotypes (cultivars) reported herein, stability estimates showed that Elgin and Davis cultivars were more stable than the others in seed yield, 100-seed weight and oil and protein contents. In addition, these two soybean cultivars gave the highest overall mean values of these characters. These results were confirmed with those of Singh and Chaudhary (1985a) and Vernetti *et al.* (1990).

Results of the present study might further reveal that two genotypes *i.e.*, Elgin and Davis may be suitable for growing in a wide range of environments and they could be used for commercial production or for breeding soybean cultivars suitable for growing in a wide range environment.

References

Angeles, J.B. (1987) Phenotypic stability of soybean in Peru. *Soybean Genetic Newsletter.* **14:** 120-124.

A.O.A.C. Association of Official Agriculture Chemists. (1980) *Official and Tentative Methods of Analysis.* 11^{th} ed. Washington D.C., USA.

Arrieta, G., Mendoza, A. and **Castiblanco, L.** (1990) Adaptability and phenotypic stability of six soybean cultivars. *Bulletin-Programa Cooperative de Investigation Agricola* **4:** 27-34 (cited after *Plant Breed Absts.* **61:** 4943, 1991).

Becker, H.C., Geiger, H.H. and **Morganstern, K.** (1982) Performance and phenotypic stability of different hybrids types in winter wheat. *Crop Sci*. **22:** 240-344.

Bhatinagar, P.S. and **Tiwari S.P.** (1989) Phenotypic stability analysis of yield in soybean. *Bio-vigyanam.* **15:** 90-93.

Carver, B.F., Burton, J.W. Carter, T.E. and **Wilson, R.F.** (1986) Response to environmental variation of soybean lines selected for altered unsaturated fatty acid composition. *Crop Sci.* **26:** 1176-1181.

Eberhart, S.A. and **Russell, W.A.** (1966) Stability parameters for comparing varieties. *Crop Sci.* **6:** 36-40.

Finlay, K.W. and **Wilkinson, G.N.** (1963) The analysis of adaptation in a plant breeding programme. *Aust. J. Agric. Res*. **14:** 742-754.

Konwar, B.K. and **Talukdar, P.** (1986) Stability analysis of yield and its components in soybean. *Crop Improve.* **13:** 172-175.

Perkins, J.M. and **Jinks, J.L.** (1968) Environmental and genotype environmental components of variability. 111. Multiple Lines and Crosses. *Heredity.* **23:** 339-356.

Pfahler, P.L. and **Linskens, H.F.** (1979) Yield stability and population diversity in oats (*Avena* Sp.). *Theoret. Appl. Genet*. **54**: 1-5.

Primoma, V.S., Falk, D.A., Tanner, J.W. and **Rajcan, I.** (2002) Genotype × environment interaction, stability and agronomic performance of soybean with altered fatty acid profiles. *Crop Sci*. **42:** 37-44.

Rao, M.S.S., Mullinix, B.G., Rangappa, M., Cebert, E., Bhagsari, A.S., Sapra, V.T., Joshi, J.M. and **Badson, R.B.** (2002) Genotype × environment interaction, and yield stability of food-grade soybean genotypes. *Agron. J.* **94:** 72-80.

Raut, V.M., Halvankar, G.B. Taware, S.P. and **Patil, V.P.** (1992) Stability analysis of soybean varieties in non conventional summer seasons. *Biovigyanam* **18:** 67-69. (Cited after *Plant Breed. Absts.* **64:** 7091, 1994).

Sediyama, C.S., Oilveira, L.O. and **Cruz, C.D.** (1990) Analysis of phenotypic stability in soybean varieties by means of simple and segmented linear regression. *Revista Ceres*. **37:** 513-518. (Cited after *Plant Breed Absts.* **62:** 467, 1992).

Shukla, G.K. (1972) Some statistical partitioning genotype environmental components of variability. *Heredity*. **29:** 237-245.

Singh, O. and **Chaudhry, C.D.** (1985a) Responsiveness in soybean for biological yield. *J. Oilseeds Research.* **2:** 50-53.

Singh, O. and **Chaudhry, C.D.** (1985b) Stability analysis for protein and oil content in soybean. *J. Oilseeds Research.* **2:** 57-61.

Steel, R.G. and **Torrie, J.H.** (1980) *Principles and procedures of statistics*. 2nd ed. McGraw-Hill, New York.

Vernetti, F., Gostal, M.F. and **Zonta, E.P.** (1990) Phenotypic stability of soybean cultivars in the South east of Rio Grande do Sul. *Agropercuaria Brasileira.* **25:** 1592 1602 (Cited after *Plant Breed Absts.* **61:** 11808, 1991).

التفاعل بين التراكيب الوراثية والبيئة وثبات محصول البذور ونسبة الزيت والبروتين في عدة تراكيب وراثية لمحصول فول الصويا

فتحي سعد النخلاوي

قسم زراعة المناطق الجافة ، كلية الأرصاد والبيئة وزراعة المناطق الجافة

جـــــدة – المملكة العربية السعودية

المستخلص. أجريت هذه الدراسة في منطقتين بيئيتين مختلفتين: الإسكندرية والحمام بجمهورية مصر العربية خلال سنوات ٢٠٠٠، ٢٠٠١، ٢٠٠٢، ٢٠٠٣ وذلك على عشرة أصناف (تراكيب وراثية) من فول الصويا وتم تقدير مقياسين للثبات هما: معامل الانحدار الخطي (b) والانحراف عن خط الانحدار (S_d^2) لكل تركيب وراثي. وأظهرت النتائج أن التفاعل بين التراكيب الوراثية × البيئات سواء السنوات أو المناطق كان معنوياً للصفات التي درست جميعًا وكان مدى قيم معامل الانحدار (b) لصفة طول النبات من ٠,٦٧ – ١,٤٧ ولمحصول البذور من ٠,٥٦ – ١,٥٧ ولوزن مائة بذرة من ٠,٣٩ – ١,٤٧ ولنسبة الزيت من ٠,٦٦ – ١,٤٧ ولنسبة البروتين من ٠,٦٨ – ١,٥٦ وقد كانت قيم الانحراف عن خط الانحدار (S_d^2) معنوية في ثلاثة تراكيب وراثية لصنفي طول النبات ونسبة البروتين وفي أربعة تراكيب وراثية لصفات محصول البذور وفي ثمانية تراكيب وراثية لوزن المائة بذرة ولسبعة لنسبة الزيت في البذور. أظهر الصنفين Elgin ، Davis درجة عالية من الثبات الوراثي من بين كل الأصناف العشرة وذلك تحت المناطق المختلفة وفي السنوات الأربعة وكانا الأعلى في محصول البذور ونسبة الزيت والبروتين.